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GUIDELINES

for

Direct-Seeding Longleaf Pine

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The direct seeding of longleaf pine has received a large impetus from foresters whose confidence in the species prompted them to make exploratory seeding trials. Their cooperative efforts furnished basic information on the requirements for longleaf seeding in the years before effective repellants were developed. The following persons and organizations merit special recognition:

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Cover: *Direct seeding is bringing longleaf pine back to many acres of its native range.*

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Figure 1. *The major breakthrough in developing successful seeding techniques for the southern pines was the finding of an effective bird repellant.*

GUIDELINES FOR DIRECT-SEEDING LONGLEAF PINE

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In the past few years, direct seeding of longleaf pine has moved from the exploratory stage to full operational use. This achievement culminates a dozen years of intensive study of a forest regeneration technique that has long intrigued foresters by its apparent simplicity.

Direct sowing of pine has been especially appealing to owners of the cutover longleaf lands, where seed trees are usually inadequate for natural regeneration, and where planting of this species is unreliable. Wide acceptance of direct seeding as a method of restocking longleaf land promises to keep this valuable species in the pine forests of the South.

Since 1947, when the first direct-seeding test was installed by the Alexandria Research Center, 19 field-plot and pilot-stage studies have been completed. While these dealt with all aspects of the topic, the principal objective was control of seed losses to birds and mammals. After a 1953 study demonstrated that a chemical seed coating would repel birds, progress was rapid. In the past four years, Louisiana landowners have seeded 42,300 acres on 31 separate projects.

Invaluable experience has been gained from the efforts of landowners whose interest prompted many of the earlier exploratory trials. Large-scale seedings furnished a means for evaluating the mass effect of seed predators, and, later, critical repellant testing that was impossible to achieve on small plots.

Direct seeding in essence involves the process of supplying viable seed to prepared forest sites in the proper amounts and at suitable seasons of the year so that germination of the seed in place will result in adequate stocking. Achieving this objective economically requires accurate distribution of seed and protection of seed and seedlings against predators. Each major aspect of longleaf pine direct seeding, from initial planning to management of the stand, is discussed separately in the following sections. As the discussions embody the results of rumerous studies and the conclusions from many operational trials, no attempt has been made to document or analyze each study and pilot test.

The research and field trials on which these guidelines are based were completed entirely within the longleaf pine type in central and southwestern Louisiana. Direct seeding can probably be used to regenerate longleaf pine throughout its natural range. However, variations in climatic or biotic conditions may require some modification of the procedures developed in Louisiana. For example, when rodents are a limiting factor, effective chemicals for their control must be included in the seed coating. Where soil conditions are adverse, such as in the Florida sandhills, very intensive site preparation may be essential. Geographic variations in the amount and distribution of rainfall can alter the sowing dates or seedbed treatments recommended for Louisiana conditions. Trials east of the Mississippi River should include local study of the factors affecting seed losses, seed germination, and initial survival. Results from a single test should be interpreted with caution. Variations in the biological factors involved, together with fluctuations in the climatic influences from year to year, will often necessitate several years of testing before the necessary modifications in techniques for a local area are apparent.

A list of references has been provided for readers interested in phases of the subject that are beyond the scope of this paper.

PLANNING FOR LONGLEAF SEEDING

Planning for the direct seeding of longleaf must take cognizance of several basic factors. Adaptability of longleaf to the sites in need of regeneration must be weighed, along with the stringent requirements of this species for intensive management and protection while the stands are young. When it has been decided that longleaf is suitable to the site in question, early planning should be directed toward the protection of seeds and seedlings.

Site Selection

It is tempting to try direct seeding first on sites where planting has failed or appears unlikely to succeed. A sounder policy is to confine initial trials to the better, easier sites and move cautiously to the adverse ones as experience is gained.

Longleaf does well on a wide variety of soils in the Gulf Coastal Plain. Its performance on the drier sites is notable, and some foresters value it also for its ability to survive and grow in areas where the incidence of wildfires makes loblolly or slash pine a risky choice.

In theory, longleaf can be seeded on all sites that it occupied in the virgin stands. In practice, some of these sites may present difficulties.

Many good longleaf sites are dominated by scrub hardwoods. Trials in a few stands of post-size blackjack oak and post oak indicate that such areas can be seeded if complete control of the hardwoods is achieved before or very soon after pine is seeded (fig. 2). Any method that will eradicate the overstory and prevent sprouting from the rootstocks is satisfactory. The practice of delaying hardwood control until there is assurance of first-year pine survival is inadvisable. Though longleaf seedlings will survive for a year under a hardwood canopy, their response to delayed release is slow. By contrast, seedlings released in their first season can develop the vigor they need to get above the heavy growth of herbaceous plants that usually follows complete hardwood control.

Hardwood areas tend to have large populations of seed-eating mammals, particularly rodents, during the germination season. While rodents ordinarily are not a serious threat to November sowing on open land, damaging numbers of them may be encountered on sites with a uniform cover of scrub hardwoods. Seeding on such areas requires the addition to the seed coating of a chemical which will repel or kill persistent seed-eating rodents.

Figure 2.
Longleaf seedlings require prompt and complete release from competing hardwoods. These 4-year-old trees were released early in the first season after germination. The oak stumps were treated with a chemical to prevent sprouting.

Common to the area that originally supported longleaf are the "flatwoods," broad tracts of sandy or silt-loam soil whose internal drainage is impeded by a shallow hardpan. Surface drainage also is poor, though the flatwoods are not necessarily level. While these lands once supported longleaf, seeding and planting both run considerable risk from unfavorable weather. These sites can be as droughty as sandy ridgetops, for the moisture in the shallow soil above the hardpan is quickly depleted. There is evidence, too, that intensive site preparation such as double disking is ineffective in reducing heavy seedling mortality during severe dry periods in the first summer. On the other hand, these sites tend to flood for extended periods when heavy rains fall during the germination season. Longleaf seed can tolerate brief flooding, but frequent or extended inundation causes germination failures. While seeding on flatwood sites has met with moderate success, it should be recognized that greater risks are involved.

Planning for Protection

Adequate protection of both seed and seedlings is vital. Every seeding project encounters many hazards between the date of sowing and the time when the trees are in active height growth. The most obvious risk—loss of seed to birds, insects, and rodents during the germination period—can be averted by using a repellent seed coating. Post-germination hazards should receive considerable attention during the planning stage, as the heavy mortality of new seedlings can be as disastrous as the total loss of seed.

Fencing is a prerequisite on most sites where livestock roams freely. No matter how it is regenerated, young longleaf cannot tolerate even moderate grazing by cattle, sheep, or goats. Hogs, even in small numbers, are fatal.

Under open-range conditions, fencing raises multitudinous problems. To keep the per-acre cost of a hog-proof fence down, large areas must be enclosed, but if local-use cattle grazing is permitted, light cross fences are usually also required. Land heavily grazed by cattle is best fenced 6 to 8 months prior to seeding, so as to conserve the new stand of grass that develops after the preparatory burn.

Within their ranges, town ants and pocket gophers ("salamanders") can be very destructive on well-drained sites. The ants must be controlled well in advance, for they begin their work as soon as the seeds germinate. Generally some follow-up treatments will also be needed before the seedlings start height growth. Pocket gophers are not a threat until the second or third year after germination, but control before seeding will simplify the task of keeping down populations thereafter.

The probable need for at least one prescribed burn for control of brown-spot needle blight should be considered. If installed in advance of seeding, the firebreaks required for such burning will reduce the hazard of wildfire.

Burns to control brown spot are generally made after the seedlings have passed their third growing season. Reinforcement seeding on areas with inadequate reproduction must be timed so that the fires will not seriously damage the different age classes. Assignment of other species to sites within a longleaf seeding area is inadvisable, especially where the brown-spot hazard is high. Islands of an unburnable species or age class run up the cost of burning, partly because they prevent the use of inexpensive headfires. They also are sources of brown-spot reinfection.

SITE PREPARATION

A light grass rough, such as develops after a burn made 6 to 8 months before seeding, has proved to be the best seedbed on most sites. Fresh burns and disked strips have also been seeded successfully. Each of these site treatments, however, has specific limitations.

A light rough was recommended after it was recognized that old roughs prevent longleaf seed from reaching the mineral soil, and after operational trials had demonstrated that untreated seed on a fresh burn is vulnerable to heavy bird attack. Even with effective bird repellants, a light rough is generally preferable to a fresh burn, as it provides a more favorable microclimate for germination by reducing the drying effect of wind and sun and by accumulating dew. This effect was demonstrated in a 1954 trial of repellant-treated seed on both types of seedbeds. Soil moisture was ample when the 180-acre project was seeded on No-

vember 22, but no rain fell for 19 days thereafter. The soil surface within the burned area became so dry that much of the germinating seed failed to root. The tree percent (proportion of seeds that produced seedlings) after 41 days was 23 on the fresh burn and 35 on the light rough.

When soil moisture is not critical, freshly burned seedbeds are satisfactory and may have some advantages. Seeding on a fresh burn is often necessary when unexpected seed becomes available or bad weather interferes with spring burns. Autumn fires, as opposed to spring burns, provide better control of brown spot on areas with infected natural seedlings, greater reduction of rodent populations, later control of hardwood sprouts, and slightly faster juvenile growth of pine seedlings. Fresh burns should not be relied upon completely because in wet seasons they may be difficult to accomplish just prior to seeding. A safe policy is to burn in April or May, and reserve fall burning for special contingencies. Fresh burns are always superior to grass roughs more than one year old. They are not recommended on rolling sites because surface runoff during heavy rains often washes the seed and dislodges seedlings before the radicles have entered the ground.

In preparing sites, the influence of adjoining areas should be considered. When the seedbed burn is made, a buffer area should be burned if possible. Grass roughs older than two years often harbor numerous rodents and other small mammals, but a buffer strip of 5 to 10 chains in width should markedly reduce rodent damage on the periphery of the seeded area.

On dry sites, thorough disking improves first-summer survival by eliminating much of the vegetation that competes with pines for soil moisture. On good sites, disking will promote seedling growth if brown spot is not severe, but it must be complete enough to kill most of the native perennial grasses. The best procedure is to burn in the winter before seeding and then disk twice during late summer. To kill grass roots, initial disking should be done during hot, dry weather. Relatively heavy equipment is needed. The second disking can be done with lighter equipment 3 to 6 weeks after the first. A single disking with light or medium equipment during the fall months just before seeding is of questionable value, for partial control of competing vegetation is of small benefit.

The cost of the heavy treatment that is needed to remove native grasses on open sites can be held down by disking in strips. Disking 8-foot strips, spaced 8 feet apart, will require approximately one-half mile of equipment travel per acre for each disking. Less seed is required than for overall sowing, especially if sowing is confined to disked strips.

The benefits of disking should be weighed against the disadvantages. A large investment in equipment for disking and seeding is needed. Simple broadcast sowing—whether from the ground or the air—has not proved satisfactory on disked sites. So far, good results have been achieved only with mechanical seeders that press the seed into contact with firm soil. This fact limits operations to the capacity of tractor-drawn seeders, and prevents working on heavy soils in wet weather.

Disked soil, like burned sites, dries quickly after a rain. Consequently, light rains, which can sustain germination on a rough, are often ineffective on disked soil. On the other hand, heavy rains can be damaging, especially if the disking impedes natural drainage. The hazard of flooding can be reduced somewhat by elevating or ridging the soil in the final disking. If elevated, disked strips must be run at right angles to the topographic contours to facilitate drainage.

A final consideration is the brown-spot hazard. The intensity of brown-spot infection varies from place to place. Seedlings on some areas have remained free of the disease for five years, while elsewhere two or more control burns have been required to get a stand out of the grass. By exposing mineral soil, disking can increase the rate of infection and necessitate additional burns. On high-hazard areas, the full benefits of disking can be realized only when a brown-spot control spray is used (fig. 3).

SEED PROCUREMENT

Early planning for seed procurement is essential. A landowner has three alternatives. He may either collect and extract his own seed, collect cones and have the seed extracted by a commercial dealer, or buy cleaned seed. All

Figure 3.
These pines were seeded on disked strips and sprayed once for control of the brown-spot disease. They are now in the middle of their fourth growing season.

three methods have merit, and the landowner's choice will depend on the supply of cones in his area, his facilities for drying cones, and the cost of commercial seed. If commercial seed is to be used, it is advisable to place orders at least six months in advance. Usually suppliers will accept orders by June or July if they think that a crop is in prospect.

A major difficulty in longleaf seeding has been the procurement of large quantities of fresh seed for November sowing. Early failures with stored seed of unknown viability led to the assumption that fresh seed was essential.

Recent trials have shown that stored seed can be used if viability is maintained at a high level. In the fall of 1956, approximately 3,000 pounds of one-year-old (1955) seed were sown by 5 Louisiana landowners, along with 5,000 pounds of fresh seed (1956). No important differences were detected in either total germination or rate of germination. On one 450-acre tract, fresh seed yielded 5,100 established seedlings per acre, while stored seed produced 4,600. All sowing was at the rate of 3 pounds of seed per acre. In the fall of 1957, stored seed was used entirely on one 1,800-acre area with satisfactory results. Moisture during the germination period was ample in both years. The performance of stored seed when moisture is critically low has not been tested adequately.

Cold storage of longleaf seed for at least one year is practical. Excellent viability can be maintained at storage temperatures between 0° F. and 32° F. if the moisture content is held between 8 and 10 percent. These conditions can be met by drying the seed in a forced-air cone kiln, then storing it in sealed drums. Failures of earlier trials with stored seed were due largely to storage at moisture levels of 18 to 20 percent. Studies now under way indicate that 3-year storage may be feasible.

In purchases of seed, whether fresh or stored, minimum standards of quality and purity should be specified. Variations in cone maturity, cone storage, seed-extraction methods, and the equipment for dewinging and cleaning can cause wide variations in different lots from the same seed year.

Unless fresh seed is damaged by improper handling, germination of 75 to 90 percent (sound-seed basis) can be expected. With fresh seed, the general procedure has been to omit a pre-sowing germination test. Stored seed should be thoroughly tested so that adjustment in the sowing rate can be made if the germinative capacity is below 70 percent. To what extent seed can deteriorate in storage and still be acceptable has not been determined. Low viability can be partially compensated by increasing the sowing rate, but seed that performs poorly in laboratory tests may do even worse amid the rigors of the field. When viability drops to 50 percent or less, the seed is of questionable value for direct seeding.

Cleaning to 95 percent sound seed is easily attained, and should be specified. Impurities should be held to less than 2 percent by weight. At best, precise sowing of repellant-coated longleaf seed is not easy. Trash and poorly dewinged seed make the job difficult to the point of impossibility, especially when airplanes are used. Empty seeds are an unnecessary burden.

Since 1948, the price of clean seed has ranged from $0.89 to $3.25 per pound, mainly in response to variations in the supply. The price

will tend to stabilize as more suppliers enter the market, but short crops are likely to inflate costs until storage facilities are developed and wider experience is gained with stored seed.

The irregularity of generally good longleaf seed years is well known, but abundant cone crops occur nearly every year somewhere within the species' range. To obtain adequate supplies of fresh seed, landowners sometimes draw on distant sources. While it is recognized that geographic races of longleaf pine exist, the hazard of moving seed beyond its distinct geographical zone has not been so clearly demonstrated as for shortleaf and loblolly pine. Georgia seed, used in Louisiana during 1953 and 1954, performed satisfactorily in respect to germination, survival, and juvenile growth. Within the past 10 years, the second-growth stands in southwest Louisiana have produced a collectible cone crop at intervals of about 3 years—in 1948, 1951, 1955, and 1958. To direct-seed longleaf annually with fresh seed means that non-local sources must be relied upon in two years out of three. The alternatives are to develop storage facilities for local seed or to synchronize operations with good local crops, which generally can be predicted a year in advance.

Proper handling of fresh seed is often neglected when large quantities are involved. Longleaf seed can deteriorate rapidly if stored at high temperatures—above 80° F.—or if the moisture content is too high. Moisture content of fresh seed ordinarily ranges from 15 to 25 percent, depending on the method of extraction. While this is excessive for long storage, the seed can be kept for short periods without refrigeration in a cool, well-ventilated room, and if bulking or close stacking is avoided. For storage of more than 7 to 10 days, refrigeration is the safest procedure.

Prolonged bulk storage after the repellent coating has been applied should be avoided (see p. 9).

BIRD AND ANIMAL HAZARDS

Correct evaluation of the bird and mammal hazards is the most difficult aspect of a seeding project. Judging animal populations requires considerable experience. In their early seeding trials, foresters often underestimate the biological hazards on a specific site. Frequent and detailed observations, as well as knowledge of seasonal population cycles, usually are required to detect predators. Birds are particularly difficult to evaluate because the troublesome species such as the meadowlark and blackbird fluctuate widely in their daily activity, and when seasonal migration begins bird numbers increase suddenly. However, either of the two tested chemical repellants—Arasan and anthraquinone—obviate the bird problem in longleaf seeding.

Small mammals are not sensitive to these repellants. Hence, a prospective site should be examined for gross evidence of unusual concentrations of such seedeaters. The offenders include shrews and the common field rodents such as the harvest mouse, white-footed mouse, and the cotton rat. Of the larger animals that are known seedeaters, the cottontail rabbit is the most widely distributed. Raccoons, opossums, and skunks are sometimes troublesome locally.

Much remains to be learned about the ecology of shrews and small rodents that inhabit the longleaf pine type. Trapping records and observations form the basis for the following general statements:

Wide seasonal fluctuations occur on upland sites, with populations usually peaking in late January or February. Apart from these seasonal variations, shrew populations appear to be cyclic, whereas the numbers of small rodents are fairly consistent from year to year.

The October-November population on areas burned in the previous spring is low when compared to that on similar unburned sites, but after the mid-winter population peaks are reached shrews and rodents inhabit all cover conditions, including fresh burns.

All rodents and shrews are voracious seedeaters. The Arasan compounds will deter these animals, but are not effective when populations are heavy. Under such conditions a toxic chemical must be included in the seed coating.

In Louisiana's longleaf type, a catch of 1 or 2 shrews or rodents per 100 trap nights in October and November might be considered normal. A catch of 5 to 10 animals per 100 trap nights indicates an unusually high pop-

ulation for open sites with a light grass rough. By mid-January, 15 to 20 animals frequently can be taken in 100 trap nights.

An alternative to trapping is the seed-spot technique. Small cleared places sown with 50 untreated seeds will serve the purpose. A spot visited by an animal during a night of exposure is treated as a trap catch. Spots should be in transect lines spaced so as to sample adequately the various cover conditions on an area. Locations on the transects should be at least 5 chains apart. Evaluation of results requires some familiarity with the distinction between bird and small-mammal damage to untreated seed. Figure 11, page 15, illustrates typical damage caused by some of the most prevalent predators.

Raccoons, skunks, and opossums usually are not numerous. Normally, cottontail rabbits are not a serious threat. Populations vary from year to year, however, and may reach levels of one animal for two acres on upland sites. When fresh droppings are found on 30 to 40 percent of milacre sample plots, a high population is indicated. If seeding is attempted, very careful observation of seed and seedlings is essential. Hunting is the most practical control for rabbits. Night hunting is very effective, but most states require the approval of game authorities. The effect of chemical seed coatings on rabbits when high populations are encountered has not been determined. Though repelled from taking seed, rabbits may still eat seedlings during the first winter after germination.

CHOICE OF A REPELLANT

Prior to the 1954 season, direct seeding of longleaf pine on an operational scale was a hit or miss proposition. Success or failure hinged on the prevalence of birds during the germination period. Early seeding was resorted to in an attempt to avoid losses to fall migratory birds, and shotgun patrols were employed to scare birds.

In a preliminary test in 1953, Morkit[1] and sublimed synthetic anthraquinone showed considerable promise as bird repellants. A 180-acre pilot test in 1954 demonstrated that Morkit, which contains anthraquinone as the active ingredient, effectively repelled most species of birds common to open sites. Use of repellants expanded rapidly in 1955, and both Morkit and anthraquinone gave excellent bird control on 7,000 acres. Morkit was withdrawn from the American market during the summer of 1956, but preliminary tests of Arasan[2] had indicated this chemical would repel birds and possibly rodents. Consequently, Arasan was used in the 1956 season on seven projects totalling 4,000 acres. It was also employed on approximately 10,000 acres of operational seeding in Louisiana during 1957. In addition, seven intensive small-plot studies confirmed that Arasan is a very effective bird repellant, but revealed that its rodent repellancy was not so great as originally thought.

The present choice of a bird repellant is between Arasan and sublimed synthetic anthraquinone. Either Arasan or Arasan-75 can be used. Other Arasan compounds should not be substituted because some are toxic to the seeds. Both Arasan compounds are equally effective, and at the recommended dosages cost about the same. When used with latex sticker, the wettable Arasan-75 provides a firmer seed coating than the nonwettable Arasan. Because both Arasan formulations irritate skin, eyes, and mucous membranes, they are undesirable for hand seeding, where laborers are constantly exposed to chemical dust from the seed. They can be used for aerial and tractor seeding if workers avoid prolonged exposure or wear protective masks. Anthraquinone, a non-irritating chemical, is recommended for hand seeding even though it is slightly more expensive than the Arasan compounds.

Anthraquinone and Arasan should be applied at the rate of 15 pounds per 100 pounds of seed. Arasan-75, containing a higher concentration of thiram than Arasan[2], can be used at a 10-percent concentration or 10 pounds of Arasan-75 per 100 pounds of seed.

In most cases, endrin should be blended with the bird repellant for protection of the seed against insects, shrews, and rodents. The amount should be varied according to the hazard. For early fall sowing on sites where populations of seed-eating insects or rodents are

[1] A proprietary bird repellant developed for agricultural use by German chemists, and suggested for direct seeding trials at Alexandria, Louisiana, by Professor John Kuprionis of Louisiana Polytechnic Institute.

[2] The term Arasan includes the 50 percent formulation of thiram (tetramethylthiuramdisulfide) known as Arasan, and also Arasan-75, which is a wettable powder containing 75 percent thiram.

known to be low, 1 pound of Stauffer's Endrin 50W[3] (0.5 pound effective endrin) per 100 pounds of seed provides ample protection. Where populations are high (or unknown), the concentration of Endrin 50W should be 2 pounds per 100 pounds of seed.

Many November seedings in Louisiana have been highly successful without the use of endrin. For this reason, careful consideration should be given to the dosage used. The chemical, sold mainly as an insecticide, is very poisonous to all animal life, including human beings. Under no circumstances should endrin be used alone, because it is not an adequate bird repellant and will endanger birdlife.

If used, endrin should be thoroughly mixed with the bird repellant before it is applied to the seed. Complete mixing of the two chemicals is essential to insure that all seeds have the proper amount of each. This can be done best with regular mixing equipment available at commercial chemical formulating plants. Safety precautions for handling endrin-treated seed are discussed on page 9.

An adhesive is essential for holding the repellant to the seed. Flintkote C-13-HPC asphalt emulsion and Dow Latex 512R have served well under various weather conditions. Asphalt emulsion should be mixed with water in a ratio of 1:3, by volume. Latex can be diluted with water in the ratio of 1:9. With either sticker, about one gallon is needed for 100 pounds of seed.

SEED TREATING TECHNIQUES

Methods improvised in 1954 for coating large quantities of seed with a chemical repellant have been used since then to treat at least 120,000 pounds of longleaf seed. The technique is simple, but requires planning, timing, and facilities for drying seed after treating.

Equipment consists of a mixing drum, a dipping vat and perforated seed basket, scales, and drying facilities. If inclement weather prevents sun drying, well-ventilated sheds or other buildings should be available where the seed can be spread out in thin layers.

Figure 4 illustrates simple but effective home-made equipment. The drum on the right has the top removed; it holds the sticker, into which the seed is dipped by means of the 20-inch-deep, fine-meshed heavy wire basket. The other drum is for applying the chemical. It has a close-fitting but removable cover and is mounted on an axle so that it tumbles end-over-end when the crank is turned. A single set of baffles is welded inside the drum to help mix the seed and repellant.

Figure 4. *With this simple equipment, made from 2 oil drums, a 3-man crew can treat a ton of seed a day.*

If a blend of Arasan or anthraquinone and endrin is to be used, the first step is to mix these chemicals together thoroughly. This can be accomplished in the tumbling drum or in a small cement mixer. If possible, though, it is best to have the job done in a plant that formulates agricultural insecticides.

The sticker is mixed with water in the dipping drum. If asphalt emulsion is chosen, it should be stirred until all lumps disappear—warm water gives faster action than cold. Latex mixes very quickly with water and no special precautions are needed. Either sticker should be stirred at regular intervals during the treating operation. The actual treating is done by putting 35 to 50 pounds of dewinged seed into the basket and lowering it into the sticker. The seed should be stirred with a wooden paddle. In 1 or 2 minutes, the basket is pulled up and

[3] A list of current supply sources and approximate costs of repellants and stickers is available on request.

the surplus sticker allowed to drain off for about 30 seconds. Next, the seed is emptied from the basket into the tumbler and a weighed quantity of repellant poured over it and mixed in with the paddle. The cover is then closed tightly and the drum rotated for about two minutes, after which the coated seed is spread out on a canvas to dry.

With either adhesive, it is important to apply the dry repellant while the sticker is wet. If the sticker is given time to set, excessive amounts of the repellant will be lost in the field. The time allowed for draining after a batch is removed from the immersion drum should not exceed ½ minute. When latex is used, a measured quantity can be applied directly to the dry seed in an open rotating mixer. Only the amount required to coat a batch of seed is added. This method is faster and does not require the preparation of surplus material needed for batch immersion. It is satisfactory only for latex, however, as asphalt emulsion does not weather well unless seeds are immersed in it for 1 to 2 minutes.

Aluminum powder, at a rate of about 15 tablespoons per 100 pounds of seed, hastens drying and improves flow characteristics. If used, the powder should be placed in the treating drum after the seed is mixed with the repellant.

A difficulty in local treating is the drying and handling of seed during extended periods of wet weather. Efficient aerial sowing requires 3,000 to 4,000 pounds of seed for a day's operation, and the seed must be dry enough to flow freely through the hopper opening of the plane. A safe procedure on large projects is to schedule seeding for a specific date, then treat during fair weather in the week preceding. If the seed is well dried, it can be stored for short periods in a cool, well-ventilated building. An alternate procedure is to arrange for artificial drying. Forced-air kilns operating at temperatures of 100° F. or less are satisfactory.

Arasan and anthraquinone are effective only when fully exposed on top of the sticker. Slurries, or mixtures of the dry powder with the liquid adhesive, lack full repellancy. Consequently, personnel treating seed or handling large quantities of the treated seed are exposed to considerable chemical dust. It is difficult to avoid, even when working outdoors. **Workers should be furnished protective respirators, preferably the type with a face mask covering the eyes. Their clothing should fit closely. All who work with endrin should wear rubber gloves and bathe at the end of the day. These measures prevent discomforting effects from Arasan dust. With endrin, they are essential for safety, for this poison can be absorbed through the skin.**

Seeding failures in recent years have been due largely to the improper use of the adhesive. An increase in the concentration of either the asphalt or latex is likely to slow the absorption of moisture by the seed, and thus reduce the rate of germination. Sticker concentrations below the recommended levels will reduce the durability of the coating. Dow latex, as received from the manufacturer, is a suspension of solids that will break down through improper storage and cannot be recovered. Temperatures above 110° F. or below 32° will destroy the suspension, as will storage in metal containers and dilution with very hard water. The thin rubbery coating provided by latex can be rubbed off by prolonged agitation in the mixing drum. Fresh batches of latex or asphalt emulsion should be prepared if treating is interrupted for more than 12 hours, for these preparations appear to lose their effectiveness with time.

A 3-man crew can treat a ton or more of seed per day. The limit on production usually is the amount that can be dried. Labor and materials averaged about $0.15 per pound when treating was done at the rate of 3 man-days per ton. For a typical operation in which Arasan was applied at 15 percent by weight, treating costs were:

	Cost per ton
Labor @ $1.25 per hour	
Seed treating	$ 30.00
Drying and sacking	8.00
Latex sticker—2 gallons @ $3.00	6.00
Arasan—300 pounds @ $0.88	264.00
Total	$308.00
Cost per pound $0.154	

Costs run about the same when asphalt emulsion is substituted for latex and when anthraquinone is used in place of Arasan. These estimates do not include supervision or depreciation.

RATE AND SEASON OF SOWING

A sowing rate of three pounds of dewinged seed per acre was adopted in initial studies at Alexandria and has been used in most operational seeding by broadcast methods. With fresh seed of good quality, this rate provides approximately 10,000 viable seeds per acre. The rate on disked strips has been about 1½ pounds per gross acre.

The highest tree percent in trials with untreated seed was about 25, or 2,500 established seedlings per acre. With repellants, a maximum tree percent of 60 has been achieved. However, results from most of the operational trials have ranged between 30 and 50 percent, or 3,000 to 5,000 seedlings per acre. Experience indicates that on good sites minimum initial stocking in the spring following seeding should be at least 2,000 well-distributed seedlings per acre. On poor sites the goal for initial stocking should be higher because first-year mortality will be greater. Intensive site preparation, which lowers the hazard of drought losses in the first summer, reduces the level of initial stocking needed. On disked strips 1,500 seedlings per gross acre seems adequate.

In 1957, exploratory tests of several lower seeding rates achieved an average of about 1,700 seedlings per pound of seed when predators were controlled. These and other results indicate that the rate can be reduced to two pounds per acre on favorable sites. Three pounds are still recommended for adverse sites.

The foregoing recommendations presuppose seed of good quality. Fresh longleaf seed, properly handled and thoroughly cleaned, will have about 3,400 viable seeds per pound, with some variation by year of collection, source, and moisture content. In estimating quality, sufficient weighed samples of a lot should be counted and cut open to provide a numerical estimate of the sound seed in a pound. Germination of fresh sound seed averages about 80 percent, but may range from 70 to 95 percent in a single season. Unless damage in extraction or handling is suspected, fresh seed can be sown without waiting for the results of a germination test, which requires about two weeks. Even if sowing proceeds, however, a sandflat or a screened field-test of the seed may provide a useful record. With stored seed, pre-sowing testing should always be scheduled. Adjustments in the rate of sowing can be most readily computed when results are expressed in terms of viable seeds per pound. The test lots should be selected before the repellent coating is applied. With treated seed, laboratory or sandflat tests often underestimate germinative capacity in the field.

Optimum conditions for seeding longleaf in Louisiana usually occur in November. It is inadvisable to sow before the maximum daily temperatures have dropped below 80° F. and the soil has become moist enough to sustain germination. Occasionally, in dry seasons, it is necessary to wait until the first or second week of December, but most operations have been completed during the last two weeks of November.

Spring sowing—in March—has been moderately successful on disked soil. The principal disadvantage of late-season germination is the sensitivity of the very young seedlings to drought. In Louisiana, where damaging early droughts can be expected in about one year out of two, spring germination increases the hazard of severe first-season losses. Spring seeding on disked strips should be completed before maximum daily temperatures during the germination period rise above 80° F. Spring sowing on non-disked sites cannot be recommended except as exploratory trials in areas where early summer droughts are less prevalent than in central Louisiana.

SOWING METHODS

Longleaf seed can be distributed by hand, by tractor-operated machines, or by aircraft. Each method differs somewhat in cost and in the conditions under which it is most effective.

Hand seeding.—For broadcast seeding on small areas, the hand-operated "cyclone" seeder (fig. 5) is very economical. It is especially useful for sowing irregular openings to supplement natural seedfall.

Hand seeding has several limitations. Foremost, perhaps, is the high labor requirement. To sow an acre requires a half-mile of walking. An experienced man can seed about 20 acres of open land per day. On rough terrain or where brush interferes, efficiency is reduced.

Exposure of personnel to dust from the repellant coating restricts hand seeders to small

Figure 5. *Hand-operated "cyclone" seeders will distribute seed accurately at a rate of 20 acres per man-day, but are not practical when the repellant on the seed is toxic or irritating to the operators.*

Figure 6. *Seeding on disked strips requires special tractor-mounted machines that meter the seed at regular intervals and press it into contact with firm soil. (Photo by Louisiana Forestry Commission.)*

jobs or to operations in which anthraquinone is the only repellant. Sowing Arasan-treated seed by hand is possible if tight clothing and respirators are worn, but this is not a practical procedure for major projects.

Tractor-seeding.—Three types of tractor-operated seeding equipment have been developed.

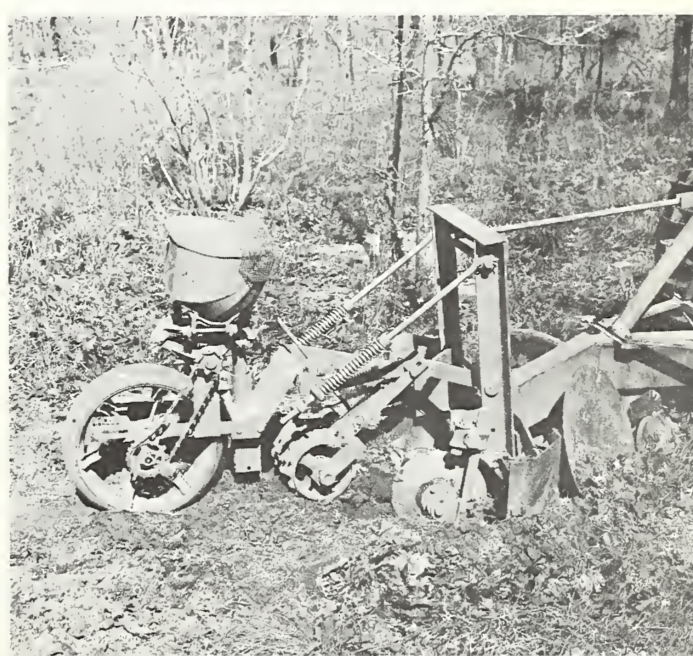
The tractor-mounted cyclone seeder can be used for broadcast sowing on level terrain. This implement, designed for sowing agricultural crops rapidly, can cover three to four times as much land per day as a hand-operated model.

Special machines have been constructed to sow longleaf seed on disked strips. These are modified grain drills that meter the seed at regular intervals in a row. Simple broadcasting on disked soil has not been completely satisfactory because longleaf seed may germinate erratically when it is not in firm contact with loose soil and because seeds or seedlings are likely to be lost through silting. For those reasons, some machines are designed to place a row of seed behind each track of a light crawler tractor (fig. 6). The tracks firm the soil before the seed is dropped, then rollers press the seed into the soil.

On flatwood sites it is necessary to elevate the rows. This is accomplished in the final harrowing with a small disk that breaks out the center of the strip and forms two ridges approximately 4 feet apart. The obvious limitation of machines that operate in direct contact with the soil is that imposed by wet ground. When soil moisture conditions are suitable, however, the machines are capable of seeding 40 to 60 acres per day.

Another mechanized seeder, developed recently for the sandy coastal soils of Alabama and western Florida, is the H-C Furrow Seeder (fig. 7). It sows a row on an elevated ridge

Figure 7. *This recently developed machine sows pine seed on an elevated ridge within a scalped furrow.*



within a scalped furrow. Site preparation and sowing are done simultaneously. Preliminary trials indicate that the furrow seeder is capable of covering approximately 20 acres per day when rows are spaced 8 feet apart.

The cost of mechanized seeding can be estimated from the amount of equipment travel per acre. Sowing on 8-foot disked strips that are spaced 8 feet apart requires approximately one-half mile of travel per gross acre. Broadcasting with tractor-mounted cyclone seeders also requires about one-half mile per acre, while furrow seeding on 8-foot centers necessitates one mile of equipment travel per acre.

Airplane seeding.—The use of aircraft has expanded rapidly since 1955, when the seed distributor for light agricultural planes was altered to permit close calibration of longleaf seedflow. This modification, described on p. 13, has been used with consistent accuracy on approximately 28,000 acres.

The main advantage of aerial seeding is its speed, which permits taking advantage of optimum germination conditions. Another advantage, a principal one in some cases, is that the type of repellent seed coating is not restricted, provided that seed handlers observe caution when Arasan and endrin are used. Nor are aircraft hampered by rough terrain, hardwood brush, wet ground, or other factors that reduce the efficiency of ground methods.

Aircraft also have limitations. Costly errors in the seeding rate can be made with a plane capable of distributing 3,000 to 4,000 pounds of seed per day. Accurate work requires properly calibrated equipment, careful control of seedflow by the pilot, and a well-supervised ground crew. The cost of aerial seeding may restrict its use on areas of less than 500 acres, or where a convenient landing strip is lacking. Costs of contract sowing (exclusive of flagging) have ranged from $0.50 to $0.88 per acre, depending largely on size of the area to be seeded and distance to a landing strip.

All types of aircraft commonly used for agricultural work can be adapted for direct seeding. The light, single-wing type (fig. 8) is very effective because it can operate from a short dirt runway constructed on the seeding area. Frequent flights with light aircraft carrying 150 pounds of seed provide better control of the seeding rate than is possible with larger planes.

Figure 8. *Light aircraft, operating from improvised landing strips, can economically seed a large acreage in a day. (Photo by Louisiana Forestry Commission.)*

A light plane, working from a landing strip on the seeding area and adequately supported by loading and flagging crews, can seed 1,500 acres per day. Accuracy is comparable to the other methods of broadcast seeding.

CALIBRATING THE SEEDING EQUIPMENT

It is difficult to sow longleaf seed accurately and rapidly at a relatively low rate per acre. The large seed, with its asymmetrical form and soft, easily damaged outer coat, does not flow evenly, nor can it be metered readily with devices designed for smooth, hard-coated seed. The repellent coating increases the difficulty, especially when the treated seed cannot be fully dried before sowing. However, techniques have been developed for controlling the seeding rate with the equipment commonly used.

Weight of untreated seed per acre should be the basis for expressing the rate of seeding. The repellent coating increases the weight of seed 25 to 35 percent, depending upon the chemical and sticker used, the treating method, and the amount of moisture removed in drying the coating. The following data from a 1956 test illustrate the variation within a single treating operation when three different chemicals were used over an asphalt sticker:

Chemical coating	Rate of application	Weight of seed lot		Weight increase
		Untreated	Treated	
	Percent	*Pounds*		*Percent*
Morkit	25	336	475	41
Arasan	15	1,320	1,828	38
Arasan-75	15	240	293	22

The wide difference in weight increase between the two Arasan treatments was due to a differential in drying rates between large and small seedlots. Differences of such magnitude suggest that the safest procedure is to develop a weight-increase factor for each project. This can be accomplished easily by weighing the untreated seed, then weighing the treated seed as it is bagged for delivery to the field. If the weight-increase factor is 25 percent, 3.75 pounds of treated seed must be sown per acre to achieve a 3-pound rate.

Aircraft equipment has been the most difficult to calibrate accurately. In early trials it was hard to obtain the desired rates, and distribution was seldom uniform. Two sources of error were recognized. First, the long, narrow hopper opening on agricultural aircraft tends to clog or bridge over while the plane is in flight. The second source of error lay in the method of adjusting the sowing rate from seed-trap counts.

In 1955 trials, the seed-release opening was converted from a narrow slot of about 27 by 3/4 inches to three adjustable openings 3½ inches long, one at the center and one at each end of the distributor (fig. 9). These openings permit a uniform flow of longleaf seed. The modification is accomplished with a metal plate cut to fit over the sliding release gate at the bottom of the hopper. Metal wedges over the blanked-off areas direct seedflow toward the three holes in the metal plate.

Figure 9. *Longleaf seed can be distributed accurately with agricultural aircraft when the hopper release gate is covered with a metal template having three square holes. Metal wedges are added within the hopper to direct seed into the openings.*

Calibration entails the adjustment of seedflow to ground speed. Pilots experienced in low-level flying can usually maintain a constant speed and altitude. Therefore, the problem is to determine the hopper opening for the desired rate of seeding. Counting the number of seeds falling into traps or on prepared plots has been unsatisfactory for adjusting aerial equipment, mainly because it is rarely practical to take enough samples. In 1955, when the modified hopper was first tested, area control of seed weight was substituted for control by count. Weight calibration has proved accurate enough so that it is now being used not only for sowing longleaf but also slash and loblolly pine.

The procedure for calibrating aircraft equipment is:

1. Determine the weight of treated seed required per acre.
2. Determine width of the strip that the airplane will seed at each pass. Strip width is influenced by several factors, such as species, airspeed, altitude, and the type of distributor mounted on the plane. At 90 m.p.h. and an altitude of 80 to 100 feet, a plane of the type shown in figure 8 will sow a strip approximately 66 feet wide. The sowing width for other types of equipment can be checked with a trial run over a landing field or other hard-surfaced area. Some overlap should be allowed.
3. Determine the ground speed at which the aircraft will be operated, then calculate the weight of seed to be released per minute. For example, if a plane operates at 90 m.p.h. it will travel 1.5 miles per minute. During one minute of operation over a 66-foot strip it will cover 12 acres $\frac{(66 \text{ feet} \times 7{,}920 \text{ feet})}{43{,}560}$. If the weight of treated seed required per acre is 3.75 pounds, the equipment must be adjusted to flow 45 pounds of seed per minute.
4. With the plane on the ground, select an approximate hopper opening. The pro-

cedure is to load the hopper with more seed than required for one minute of operation, place open-net bags over the rear openings of the distributor, and then make a 1-minute flow test with the engine running. Start with the hopper openings at a definite setting, i.e., 1½ inches, then increase or decrease it as the actual flow per minute indicates. Usually three trials will suffice.

5. Fly a measured course over the seeding area to check the weight of seed released per acre. The 1-mile intervals between section lines are convenient for this purpose. Direction of flight should be perpendicular to the wind. On a 1-mile course, and with 66-foot strips, two flights in opposite directions will cover 16 acres. The amount of seed released per acre can be determined from the weight of seed left in the hopper after a 2-flight trial. After the remaining seed is weighed and adjustments are made in the hopper opening, the plane can be loaded for a 4-flight trial. Successive loads should be increased by 16-acre increments until the capacity of the plane's hopper is reached. After the controls have been adjusted as closely as possible, accurate seeding is up to the pilot. He must be able to maintain a uniform ground speed and detect stoppages in seedflow and correct them promptly. Area control of the sowing rate requires a constant check of the acreage covered during the operation. The pilot should be given an accurate map so that he can estimate the distance flown and acreage covered with each load of seed.

The lines that the pilot is to fly are indicated by flagmen on the ground. Ordinarily, flagging is a service provided by the landowner. Three flagmen are usually enough—one at each end of the flight line and one at the middle. More may be needed if the area contains high obstructions, for to maintain accurate flight lines the pilot must be able to see at least two flags after completing a turn, and the flag under the turning plane is usually out of view. When the lines exceed a mile in length, the terminal flags must be large and should be kept in motion while the aircraft is approaching. To avoid lost time or inaccurate seeding, the pilot should have the opportunity to discuss techniques of low-level flying with the ground crew.

Seed distribution is affected by wind velocity and altitude. Pilots vary in their reaction to wind. One will insist on calm weather for low-level flying, while another will work in moderate cross-winds if they are steady. Calm is desirable, but it is often windy during the longleaf seeding season. Consequently, some aerial seeding has been done in steady winds up to 10 m.p.h. Because of the need to maintain uniform ground speed, the flight lines should be at 90° to the wind direction.

Cross-winds affect the pattern of seed distribution, but not the width of the seeded strip. They have a windrowing effect on the seedfall pattern. Distribution upwind is shortened, while seed released on the downwind side is carried farther than usual. The net effect is alternate strips with relatively high and low seeding rates. A certain amount of windrowing can be tolerated when the alternative is to hold treated seed for an indefinite period while waiting for calm weather. Sowing in gusty winds should be avoided because they accentuate windrowing.

The plane's altitude affects strip width. Aircraft operating at heights of 80 to 100 feet will distribute seed uniformly if a constant altitude is maintained. On rolling terrain, the pilot should endeavor to clear hills by 60 feet, as below this level strip width narrows markedly with decreases in altitude.

The procedure for calibrating aerial equipment can be used for hand-operated and tractor-mounted broadcast seeders. After the seed weight required per acre and the effective strip width have been determined, trial runs are made over a measured course with a known weight of seed in the hopper. A convenient strip width for calibrating hand-operated or tractor-mounted cyclone seeders is 16½ feet. This width permits easy conversion of distance traveled to acres. A mile-long strip is equivalent to two acres. Accurate sowing with hand-operated seeders requires some practice, and operators must check constantly for stoppages.

With mechanical seeders designed for op-

Figure 10. *A station on a burned seedbed for detection of seed or seedling predators. Arrows indicate two exposed seed spots. The wire cones protect seed to be used in estimating field germination.*

eration on disked strips, the seeding rate is adjusted to the number of seeds required per 100-foot segment of strip. A rate of one pound (3,400 viable seeds) per gross acre requires about 130 seeds per 100-foot segment when strip centers are 16 feet apart.

DETERMINING SEED AND SEEDLING LOSSES

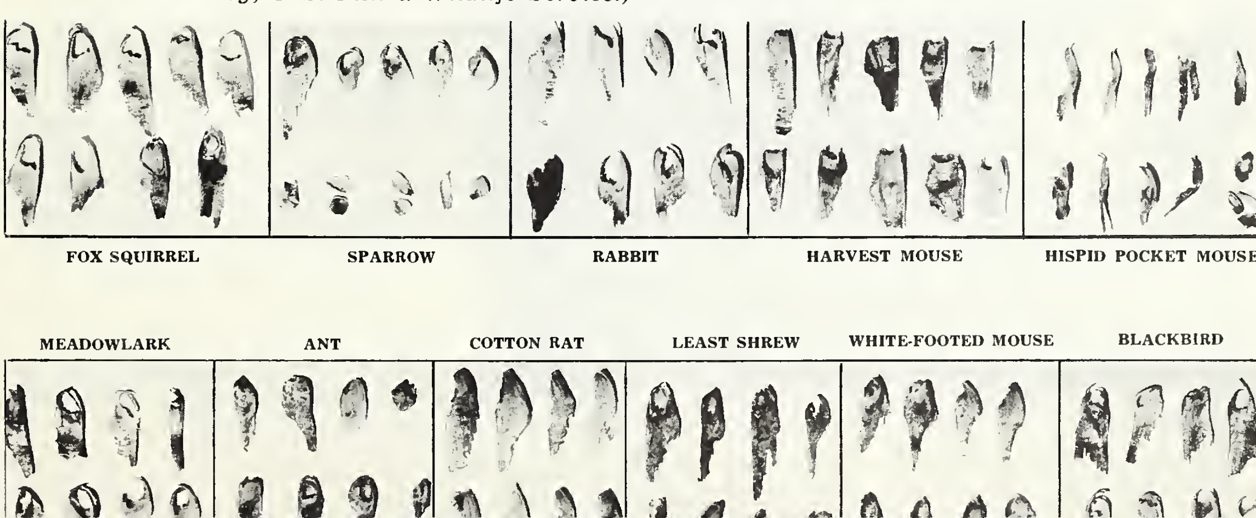
Even though repellants are used, the seeded area should be systematically observed during the germination period, especially during initial seedings when experience with local predators is not available. The installation illustrated in figure 10 is convenient for detecting major predation. In sufficient numbers on a project area, these stations will provide a good estimate of the species of predators at work, and a fair estimate of their distribution.

The station consists of an identification stake, two exposed seed spots, and one or more screened spots. The exposed spots, about four feet from the stake in opposite directions, should be cleared of vegetation with a shovel and slightly depressed to prevent seeds from being washed away by rains. Each spot is sown with 25 treated seeds, pressed gently into the soil. The protected spot receives 10 or 15 seeds, depending on size of screen cone, and serves to measure field germination. If a comparison of germination between treated and untreated seed is desired, two screened spots can be used. Hardware cloth with a ¼-inch mesh is well suited for constructing the cones. The number of stations will depend on the size of the seeded area and on the amount of data desired. About 50 stations can be examined per man-day. This number is usually sufficient to detect major depredations on areas up to several thousand acres in size.

Weekly inspections are sufficient. Identification of the animal responsible for losses may be difficult, but unless the seed is removed entirely fragments remaining on the spot often provide ample clues.

Figure 11 illustrates characteristic damage to seed hulls by the common predators. Some

Figure 11. *Characteristic damage to untreated longleaf seed by the principal seed predators in central Louisiana. These hull fragments were obtained from caged predators. (Photo by Brooke Meanley, U. S. Fish & Wildlife Service.)*



rodents have a definite method of opening longleaf seed. The harvest mouse cuts off the small end, while the cotton rat removes an edge of the seed coat. Hispid pocket mice leave long slender fragments, and the fox squirrel opens the seed coat on the flat side. But not all damage is distinctive. Fragments of seed destroyed by meadowlarks resemble those left by rabbits. The white-footed mouse cuts seed hulls in the same way as the least shrew. Except when definite types of damage are found, therefore, a predator usually cannot be identified from a few samples of damaged seed. The principal advantage of an observation station is that it entices animals to a small area. Droppings, tracks, and other indications can then be used for identification along with remnants of seed.

Feeding habits are also clues. Most species of birds are sporadic feeders. Usually they remove from 10 to 50 percent of the seed at each visit. Some small mammals remove the entire seed to places of concealment or to underground burrows, while others eat it in place. Hispid pocket mice usually take every seed on a spot and leave a neat pile of slender fragments. When the population of small mammals is low, observation stations often are undamaged during the 30- to 40-day period required for germination. When undamaged, they can be used to detect post-germination seedling mortality.

Loss of established seedlings during a relatively short period in the winter immediately after germination is a longleaf seeding problem yet unsolved. Identity of all the responsible animals or insects has not been established. Figure 12 illustrates the most frequent type of damage: clipping of the stem about ⅛ inch above the ground, with the cotyledons either consumed completely or carried off. Occasionally seedlings will be cut at the groundline, or pulled out with the radicle clipped and left on the surface. These losses are difficult to detect unless a representative sample of the seedling stand is pinned soon after germination is complete.

Since 1953, when clipping of this nature was first observed, losses averaging about 25 percent of the catch have been recorded each year. In some years serious damage was confined to 2 or 3 weeks in early January; in others, clipping continued into March. Initially, rabbits were considered to be responsible. Later the short-tailed cricket was recognized as a definite predator. In 1957, observation on study plots where 23 percent of the seedlings were destroyed during the first three weeks of March revealed that a small mammal—rodent or shrew—clips germinated seedlings. Cutworms may also be responsible.

If unusually active, rabbits can easily be recognized by their droppings and crickets by their small earthen mounds. If crickets are feeding on seedlings, fragments of the cotyledons can be found in the upper chamber of their galleries. In the absence of these two predators, shrews or one of the small rodents should be suspected.

Repellent coatings are ineffective against seedling predators, because they avoid the seedcoat entirely, even when it is still attached to the cotyledons. Until practical controls are developed, the seeding rate should be kept high enough to compensate for the post-germination losses.

Figure 12.
Predominant type of seedling loss in the first winter after germination has been clipping of the stem about ⅛ inch above the ground.

ESTIMATING INITIAL STOCKING AND FIRST-YEAR SURVIVAL

The Importance of Initial Stocking

Initial stocking denotes stand density in the spring—May or June—following germination. The level of stocking recorded then will indicate success or failure insofar as germination and the influence of seed and seedling predators are concerned. Stocking estimates after the first growing season also are needed, because first-summer mortality can be high if prolonged droughts occur.

Why estimate initial stocking? This task, requiring several man-days of labor on the average, may seem unnecessary inasmuch as survival after the first season determines whether a stand has been established. Several reasons can be cited. Accurate appraisal of the yield from various rates of seeding requires an estimate of initial stocking. Landowners seeding for the first time need the estimate for assurance, if for no other reason, that the inconspicuous seedlings are actually there. Finally, the extent of summer mortality to be expected in specific site or soil conditions can be derived only from accurate stocking estimates.

Estimating Stocking

For broadcast seeding, the line-plot method is used for estimating stocking both initially and after the first summer. Circular milacre plots are established along transect lines spaced at regular intervals on a base line. The total number of living seedlings on each plot is recorded. Average plot stocking multiplied by 1,000 provides an estimate of stand density per acre. Seedling distribution is expressed as the proportion of sample plots stocked with at least 1 seedling. Eighty percent stocking, for example, implies that 800 of 1,000 possible sample plots per acre have 1 or more seedlings. The two expressions of stocking are related. One estimates tree percent or the yield of seedlings per unit of seed; the other measures the efficiency of seed distribution. Generally, 80-percent plot stocking is achieved with hand or aerial seeding methods when the level of stocking reaches 3,000 per acre.

The number of plots required depends on size of the area, variance between samples, and degree of accuracy desired. For broadcast seeding, the coefficient of variation of the sampled stands has averaged about 100 percent. The number of samples required for a specified limit of error with 67 percent reliability is:

$$N = \left(\frac{\text{coefficient of variation in percent}}{\text{limit of error in percent}}\right)^2$$

An estimate with a standard error of $\pm$ 10 percent would require 100 sample plots. If faulty seeding techniques or other causes have increased the coefficient of variation, a larger sample must be taken for the same degree of accuracy. If seeding rates, seedlots, or sites vary within an area, it is often desirable to segregate the stocking estimate for the area into homogeneous sub-blocks. Sampling intensity must be increased for accurate sub-unit estimates unless wider limits of error are acceptable.

Estimating stocking on disked strips requires a different technique. When only a portion of the gross acreage is seeded, the estimate derived from sample plots on the strips must be adjusted to a gross acreage basis. This adjustment requires a separate estimate of the area in the disked strips. The procedure is to establish, on regular transect lines, sample plots consisting of two adjacent 6.6-foot segments of the disked strip. A location marking the common boundary of the two sub-plots is selected in an unbiased manner. Then the total number of seedlings on each sub-plot is recorded. Finally, the distances from the center of the sampled strip to the center of each adjoining strip are measured at each location. The estimate of seedling density per gross acre is calculated by multiplying the mean stocking per sample location (13.2-foot plot) by $\frac{3{,}300}{\text{average distance between strips}}$. For example, if the mean plot stocking is 10, and the strip centers average 16.5 feet apart, stand density is $10 \times \frac{3{,}300}{16.5} = 2{,}000$ seedlings per acre.

Stocking percent based on 1,000 perfectly distributed seedlings per acre is derived by multiplying the percent of stocked sub-plots (6.6-foot segments) by

$$\frac{6.6}{\text{average distance between strips}}.$$

It should be noted that stocking percent based on 1,000 seedlings per acre cannot exceed the proportion of milacres actually seeded. Full plot stocking with 16.5-foot intervals between strip centers would be 100 $\left(\frac{6.6}{16.5}\right)$ or 40 percent.

Frequently it is convenient to express stocking on the basis of 250 perfectly distributed seedlings per acre. This value for disked strips is calculated by multiplying the proportion of stocked 13.2-foot sample segments by

$$\frac{13.2}{\text{average distance between strips}}.$$

First-Year Survival

What is satisfactory stocking? As previously mentioned, the goal for broadcast seeding should be at least 2,000 initial seedlings per acre, and for strip seeding 1,500 per acre. These are approximate values suggested by experience on areas in which first-year mortality has been measured. Requirements will vary with soil types, summer rainfall means, and the degree of protection from controllable losses. On undisked sites, first-summer survival of initially established seedlings has ranged from 25 percent (1952) to 98 percent (1955), but has usually been between 50 and 80 percent. Thus a minimum initial stocking of 2,000 seedlings per acre should provide between 1,000 and 1,600 established seedlings by the end of the first growing season.

Table 1 records initial and first-year stocking for a number of operational seedings. Drought is the chief enemy of longleaf stands in their first year. The hazard is worst in the early half of the season. By July, taproots have generally penetrated to soil layers moist enough to sustain the trees through late-summer dry spells. Once seedlings are in their second or third year, droughts comparable in severity to those occurring in Louisiana during the past 10 years do not seriously affect survival.

In dry years, seedlings on disked strips tend to grow faster, both above and below ground, than those on undisked sites, for disking conserves the moisture in soil layers below 6 inches. In years when survivals of 70 or 80 percent are attained on non-disked sites, however, the performance on disked sites may not be noticeably better. As has been remarked, site preparation by disking should be considered as an insurance against droughts early in the growing season. Seedlings on disked strips have survived a 4-week May-June drought that wiped out natural seedlings in a light grass rough. Early droughts of still longer duration, however, can be fatal regardless of site treatment. When poorly drained "flats" have a tight hardpan within 12 to 18 inches of the surface, limited soil moisture capacity leads to early mortality in droughts even though disking has reduced competition.

Table 1. *Initial and first-year stocking record for 12 selected operational seedings*

Year	Seeded area	Seedbed	Seeding rate per acre	Seed age	Repellant	Stocking per acre		First-year survival
						Initial	First-year	
	Acres		*Pounds*			*Number*	*Number*	*Percent*
1951	214	1-year rough	3.36	Fresh	None	1,900	477	25
1951	210	Burn	3.33	Fresh	None	2,260	1,660	73
1952	915	Disked strips	1.70	Fresh	None	972	482	50
1953	260	1-year rough	3.07	Fresh	None	1,930	788	41
1953	182	1-year rough	3.04	Fresh	None	2,530	1,320	52
1954	65	Burn	3.40	Fresh	Markit	2,840	2,790	98
1954	110	1-year rough	3.40	Fresh	Markit	3,330	3,270	98
1955	1,110	1-year rough	3.00	Fresh	Morkit	2,558	[1]	....
1955	2,500	Disked strips	1.50	Fresh	Morkit and anthraquinone	1,900	1,200	63
1956	225	1-year rough	3.20	Year old	Arasan	4,600	2,628	57
1956	225	1-year rough	3.20	Fresh	Arasan	5,100	2,914	57
1956	172	1-year rough	2.90	Year old	Arasan	4,180	3,400	81
1956	1,035	1-year rough	2.90	Fresh	Arasan	3,330	1,940	58
1956	216	Burn	2.85	Year old	Arasan	2,658	2,411	91
1956	226	Burn	3.12	Fresh	Arasan	2,373	2,160	91
1957	890	Burn	3.00	Fresh	Arasan	4,146	[1]	....
1957	100	Burn	2.00	Fresh	Arasan-Endrin	3,406	[1]	....

[1] Not recorded.

Proper timing of control treatments for hardwood competition can improve survival. Numerous studies have shown that when hardwoods are deadened during the pines' first growing season, survival in dry years is increased in comparison to that on open sites or under comparable stands of living hardwoods. Too often the early control of woody competition is considered only as a financial risk rather than as a silvicultural necessity for pine regeneration on difficult sites.

Some losses to animals, disease, and fire can be expected after the first year. The magnitude of these losses will depend on the amount of protection and on the skill with which the established stand is managed.

STAND PROTECTION AND MANAGEMENT

After the first growing season, mortality from drought is no longer a major problem. Henceforth, growth and development depend on the adequacy of protection, and on the timeliness of the necessary management or silvicultural treatments. Requirements for protection vary with site quality and cover conditions, brown-spot infection rates, and prevalence of predators like the town ant, pocket gopher, and cotton rat. If protection from hogs and grazing animals is complete, some seedling stands may need no more management than a single (prescribed) burn for brown-spot control after the second or third growing season. Others may require intensive care such as poisoning to control town ants or cotton rats in the second season after germination, or two or more brown-spot control burns.

The prerequisite for effective management is regular and systematic inspection of the stand during the grass stage. Only by thorough periodic examinations can the need for burning be properly evaluated and the presence of predators detected. A useful procedure is to install semi-permanent plots when the initial inventory is undertaken. These plots, if well distributed, can then be used for estimating survival and for periodically appraising stand conditions. An alternate procedure is to schedule periodic inventories to record stand density, seedling damage, and the amount of brown-spot infection.

Healthy longleaf seedlings can withstand the competition of heavy stands of grass, so burning for rough reduction alone is not required (fig. 13). Optimum seedling growth is achieved

Figure 13. *When brown spot is not a problem, longleaf seedlings are capable of vigorous growth in heavy grass roughs. This 4-year-old seedling is beginning active height growth. Prescribed burning solely for rough reduction is not required.*

without burning. During their first two or three years, however, most stands develop brown-spot infections that must be controlled if the seedlings are to emerge from the grass stage in reasonable time. After they reach one-third of an inch in groundline diameter, seedlings can withstand fire with practically no mortality.

Predetermined burning schedules cannot be used in seeded stands because the rate of brown-spot infection varies widely by geographic location and from year to year. The typical infection develops gradually enough so that it can be kept under observation in the regular annual or semi-annual inspections of the stand. Only rarely is a stand in a grass rough severely infected by the end of the first season—fortunately so, as seedlings this young are vulnerable to fire. On the other hand, burning must not be deferred so long that a substantial portion of the seedlings will be in the vulnerable stage of early height growth.

The severity of infection, as recorded in December or January, should be the principal basis for deciding when the first burn is to be made. If, after 2 years, a representative sample of the stand has a low proportion (10 to 20 percent) of the needle tissue killed by the disease, burning can be deferred one year. When second-year needle kill is high (20 to 40 per-

cent) fire is needed. These are rough guides. Vigor and size of seedlings, and character of the fuel, also enter into the decision.

Burning for brown-spot control should be done late in the dormant season—in January, or early February. Fast headfires, set on cold days with steady winds, have been used for initial burning with good results. Headfires have several advantages over backfires. They are cheaper, they raise ground surface temperatures less, and they do a better job of destroying the brown-spot pathogen. Headfire burning can also be accomplished when fuel moisture is too high for backfires. Large areas can be treated in a relatively short period of time when burning conditions are stable. Headfires cannot be used under all circumstances. They may not be advisable on areas with accumulations of heavy fuels such as logging slash or hardwood debris. Nor are they satisfactory when the seedling stand is composed of two age classes—a situation found when reinforcement seeding is done in understocked natural stands.

If a second burn is needed when a portion of the stand is in active height growth, backfires are recommended to avoid killing the most vigorous seedlings. Two objectives should be kept in mind when backfiring for brown-spot control. One is to keep surface temperatures low—best accomplished by firing against a steady wind on cold days. The other is to secure a complete burn. Patchy burning can result in a rapid reinfection by brown spot.

Death of vigorous seedlings in the second or third season indicates cotton rat or pocket gopher activity. Both predators are root feeders. They are inconspicuous and can be easily overlooked until they do serious harm. Figure 14 illustrates typical cotton-rat damage on two-year-old seedlings. The rats attack longleaf seedlings at or slightly below groundline, and usually excavate a small depression in the soil. They apparently work from only one position. The damage to seedlings that are one-half-inch in diameter or larger is a half-girdle that usually heals over in the following season. Smaller seedlings often are completely severed. Cotton rats inhabit the heavy grass roughs that develop on seeded areas after the second year. Their presence is revealed by well-defined runways through the grass. They can be controlled by placing poisoned grain along runways, or by destroying their cover with fire. Control with poison is necessary only for a heavy attack in the second season when seedlings are small and vulnerable.

Figure 14. *This seedling was attacked by a cotton rat.*

While the cotton rat frequents low areas with heavy herbaceous cover, pocket gophers are usually found on well-drained slopes or ridgetops. Generally, their damage is not noted until seedlings reach one-half-inch or more in diameter. Then they feed on the entire taproot, and often pull a portion of the top into their burrows. While characteristic mounds of loose soil often indicate the presence of gophers, serious damage has been observed where no recent mound building was found. Under these conditions control is difficult, simply because the presence of the animal cannot be ascertained. It is advisable to look for gopher infestation after the initial burn for brown-spot control. Poisoned bait placed within their underground burrows is the most practical control.

After the influence of site quality is taken into account, the two principal causes of variation in growth of seeded stands in Louisiana have been the degree of site preparation and the incidence of brown spot. The combination of two intensive treatments—heavy disking and brown-spot control with a fungicidal spray—has produced the fastest early growth.

Figures 15 and 16 illustrate extremes in seedling vigor due mainly to local differences in brown-spot infection. The vigorous trees in figure 15 are four years old. They are on a site where the brown-spot hazard was low and burning during the grass stage was not required. The six-year-old stand in figure 16 was seeded in an area where the rate of brown-spot infection has been high for many years. It received three controlled burns—after the third, fifth, and sixth seasons. Generally, the growth and vigor of young longleaf stands established by direct seeding on unprepared sites will be somewhere between these two extremes. If brown spot can be controlled adequately with a single fire after the second or third season, active height growth can be expected during the fourth year after seeding.

Figure 15. *Four-year-old longleaf established by seeding on a light rough. As brown-spot infection was negligible, no prescribed burns were made.*

Figure 16. *A 6-year-old seeded pine stand in an area where brown spot reduced seedling vigor and necessitated three control burns.*

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Longleaf seed germinates quickly—often starting 3-7 days after sowing, and finishing in 4 weeks. This seedling is just ready to shed its seed coat. (Photo by Elemore Morgan.)